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Effect of flux adjustments on temperature variability in climate models

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Abstract. It has been suggested that “flux adjustments” in climate models suppress simulated temperature variability. If true, this might invalidate the conclusion that at least some of observed temperature increases since 1860 are anthropogenic, since this conclusion is based in part on estimates of natural temperature variability derived from flux-adjusted models. We assess variability of surface air temperatures in 17 simulations of internal temperature variability submitted to the Coupled Model Intercomparison Project. By comparing variability in flux-adjusted vs. non-flux adjusted simulations, we find no evidence that flux adjustments suppress temperature variability in climate models; other, largely unknown, factors are much more important in determining simulated temperature variability. Therefore the conclusion that at least some of observed temperature increases are anthropogenic cannot be questioned on the grounds that it is based in part on results of flux-adjusted models. Also, reducing or eliminating flux adjustments would probably do little to improve simulations of temperature variability.

Introduction

The recent conclusion that humans have detectably influenced climate (Santer et al., 1995) has been questioned because it is based in part on estimates of natural climate variability obtained from climate models using “flux adjustments”. These are unphysical sources or sinks of heat, moisture and/or momentum sometimes added to climate models at the ocean-atmosphere interface; they reduce the tendency of simulations of the present climate to drift away from observations. It has been asserted (e.g., by Pierce et al., 1995) that flux adjustments may suppress variability in climate models. If so, studies attempting to detect human influences on climate may have overestimated the significance of observed temperature changes, because they rely in part on estimates of natural temperature variability derived from flux-adjusted models. Our examination of temperature variability in 17 climate model simulations does not support this hypothesis. We find major differences among climate models in temperature variability, but no evidence that flux adjustments suppress temperature variability. Factors other than the presence or absence of flux adjustments are of primary importance in determining amounts of temperature variability in climate model simulations.

Results

The simulations we analyzed are 17 of the “control” (constant external forcing) simulations submitted to the Coupled Model Intercomparison Project (CMIP; Meehl et al. 1997 or <http://www-pcmdi.llnl.gov/cmip>). One simulation which used prescribed sea ice extents, and one which restored sea-surface salinities to observed values, were excluded from our analyses. In addition, we excluded the original CMIP1 submission from Washington and Meehl (NCAR) in favor of their more recent results with the Parallel Coupled Model (PCM). The models used (Table 1) are global ocean-atmosphere-sea ice general circulation models. These simulations comprise nearly all of the constant-forcing simulations performed to date with this type of model. The simulations range in length from 24 to 1085 simulated years. The simulations use constant external forcing, and thus represent estimates of temperature variability due to sources internal to the climate system (not, for example, increasing atmospheric CO₂, solar variability, or volcanoes).

Model	Nation of Origin	Flux Adjustments	Run Length (yr)	Var. 1 20 yrs	Var. 1 Full Sim's	Var. 2 20 yrs	Var. 2 Full sim's
BMRC	Australia	none	105	.0358	.0632	.205	.431
CCCMA	Canada	Heat, water	150	.0672	.0672	.274	.313
CCSR	Japan	Heat, water	40	.105	.101	.456	.464
CERFACS	France	None	40	.0657	.0609	.295	.327
COLA	USA	None	191	.0503	.0499	.264	.265
CSIRO	Australia	Heat, water, moment	100	.0646	.0619	.331	.339
DOE PCM	USA	none	300	.0977	.100	.407	.431
ECHAM1+LSG	Germany	Heat, water, moment	960	.0389	.0636	.273	.311
ECHAM3+LSG	Germany	Heat, water, moment	1000	.0563	.0712	.300	.337
ECHAM4+OPYC	Germany	Heat, water	240	.0557	.0951	.332	.421
GFDL	USA	Heat, water	1000	.0584	.0960	.413	.446
GISS (Miller)	USA	None	89	.0537	.0551	.242	.313
GISS (Russel)	USA	None	98	.0468	.0853	.333	.399
LMD/IPSL	France	None	24	.0594	.101	.255	.281
MRI	Japan	Heat, water	100	.0787	.0897	.363	.423
NCAR CSM	USA	None	300	.0793	.120	.342	.397
UKMO (HadCM2)	Great Britain	Heat, water	1085	.0980	.130	.453	.469

Table 1: List of model simulations analyzed here, and their simulated temperature variabilities. This list includes 17 of the 20 simulations submitted to the CMIP 1 project. The 4 rightmost columns give values for two measures of temperature variability; these measures are defined in the text. For each measure of variability, values are shown for both the last 20 years of each simulation and for the full length of each simulation. Simulation lengths (years) are listed in column 4.

We calculated two measures of temperature variability in these simulations. The first (“Variability 1”) is based on global- and annual-mean surface air temperatures (SATs; the exact definition of SAT varies slightly from model to model). These data were first detrended by fitting and subtracting a least-squares line; then the standard deviation of each time series of residuals was calculated. Detrending helps avoid confusing the approach of the model solution to equilibrium with long-period variability. The second measure

Figure 1: Histograms showing surface air temperature (SAT) variability in 17 climate model simulations. The left and right columns show different measures of variability (Variability 1 and Variability 2, defined in the text). In the top panels, the results are based on the last 20 years of each simulation; in the lower panels the entire length of each simulation was used. In each panel we also show a t-value and the associated “one-sided” probability that the difference in means between the two classes of models is significant. In all cases, the flux adjusted models have more variability than the non-flux adjusted models.

Figure 2: Relationship between time- and space-averaged SATs and high-latitude SAT variability in 17 CMIP simulations. The horizontal axis shows global mean SATs averaged over the last 20 years of each simulation. The vertical axis shows our “Variability 2” measure of SAT variability averaged over all latitudes poleward of 50 deg. The simulations with warmer time- and space-averaged SATs have less high-latitude SAT variability, presumably because of reduced effective heat capacity in ice-covered regions, and a smaller snow/ice-albedo feedback. The lines are least-squares fits to the non-flux adjusted (solid line) and flux adjusted (dotted line) model results. The * indicates the observed climate.

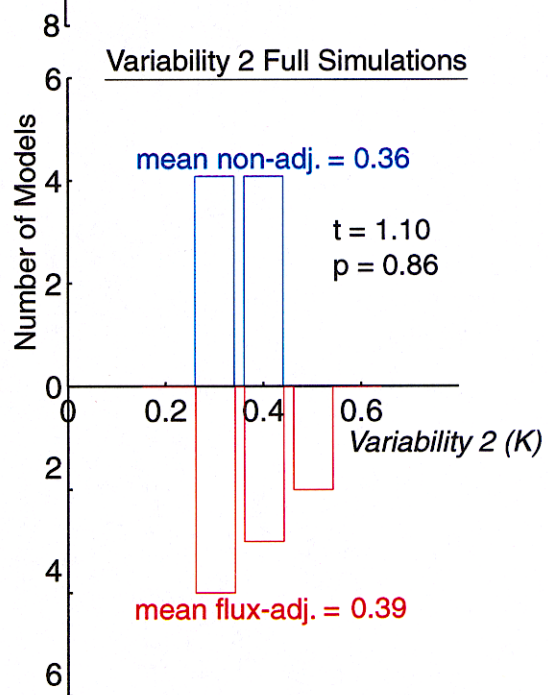
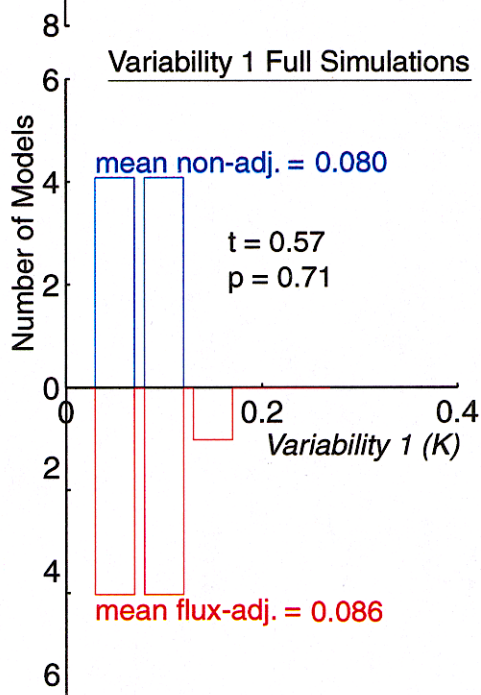
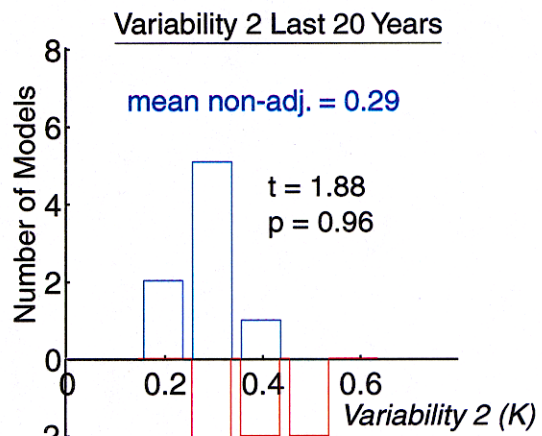
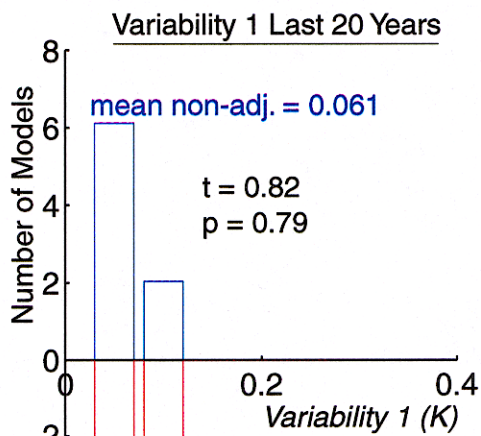
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— Flux-adjusted
— Non-flux adjusted

